Selecting Advanced Software Technology in Two Small Manufacturing Enterprises

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[1] PECA is a COTS selection methodology. The name is taken from the first letter of each of the process steps: Plan, Establish criteria, Collect data, and Analyze data.

Executive Summary

This paper documents two small manufacturing enterprises' (SMEs') efforts to select advanced software technologies for their business operations. While the two companies' market spaces are completely different, each faced business and operational issues that are common to the broad SME community. Conducting both companies' technology selection efforts concurrently allowed the Technology Insertion, Demonstration, and Execution Program to address a wide range of issues and better leverage the selection expense.

The generic selection methodology used was a downsizing of the PECA methodology augmented by Analytic Hierarchy Process (AHP) decision support (see Appendix A). PECA was developed by the National Research Council of Canada and the Carnegie Mellon® Software Engineering Institute. The body of this report describes the companies, the process, the issues, and the lessons learned during the software selection. The lessons taught us how important it is for SMEs to

- understand their business and how the proposed software will support their firm's growth strategy
- develop or use a process to assign tasks and involve stakeholders
- if necessary, involve specialists in decision support and technology adoption to help clarify issues and identify potential pitfalls
- investigate vendors and their software offerings from a variety of perspectives

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Abstract

Small manufacturing enterprises (SMEs) face a number of challenges when selecting and implementing advanced software technologies. These challenges may include the lack of awareness of the specific technologies and commercial products available, the lack of ability to select the appropriate product, and the lack of skill sets needed to utilize the selection techniques.

This paper documents the actual process and benefits of advanced software technologies adoption by two SMEs. Considerations for defining requirements and selecting a software product are described. This technical note explains the issues involved for SMEs, presents methods they can use, and provides artifacts used in this documented case.

1 Introduction

1.1 Background

Small manufacturing enterprises (SMEs) today are faced with many challenges: among them are global competition, volatile markets, and rapidly evolving technology. These challenges require SMEs to raise their performance to new levels. SMEs must operate with increased efficiency to meet the demands of global competition. They must reengineer their processes to reduce the time to market for new products. They must also continually improve their products and services to meet ever-increasing customer demands. Advanced Information Technology (IT) tools such as computer-aided engineering (CAE) and integrated manufacturing execution systems (MESs) can help SMEs achieve these goals.

The indications are, however, that many SMEs have yet to adopt advanced, commercial off-the-shelf (COTS) software tools. For example, the Air Force white paper, *Initiative for Small and Medium Enterprises*, quoted a study of 1,002 companies. According to the study, 35% of companies with 50 or fewer employees had a computer-aided design and engineering capability. For companies with 500 employees or more, the figure was 85% [Boden 99]. Similarly, a survey of 200 SMEs in southwestern Pennsylvania found that

- 28% have solid modeling capabilities.
- 23% have simulation capabilities.
- 16% use Finite Element Analysis.
- Fewer than 30% communicate directly to suppliers and customers over the Internet [Catalyst 02].

SME reluctance to adopt advanced software technologies may be attributed to various factors, barriers, and constraints. These factors include the perception that advanced software represents a cost, not an asset; the lack of knowledge of the technologies; the lack of financial resources; and the lack of expertise in technology adoption. The Technology Insertion, Demonstration, and Evaluation (TIDE) Program investigated these issues by collaborating with two SMEs to specify and select advanced software technologies. In this effort the TIDE program and the Software Engineering Institute also collaborated with the Duquesne University Institute for Economic Transformation (IET) and the National Institute of Standards and Technology (NIST).

1.2 Magdic Precision Tooling, Incorporated

Magdic Precision Tooling, Incorporated designs and manufactures sophisticated compaction tooling for the powder metal industry. Over several years, Magdic has worked with the Duquesne University IET to implement strategic business planning, cross-training, process flow optimization, and other continuous improvement activities. To maintain its growth and profitability, the company began

looking at technology improvement. Specifically, the firm identified the following areas of concern regarding its design and manufacturing process:

- The total cycle time was greater than desired.
- An opportunity existed for manufacturing process improvement.
- Processes were paper based.
- Retrieval of legacy information was difficult.
- Revision control of drawing sets was manual.
- Shop scheduling was not optimized.
- Shop capacity was difficult to monitor.

These issues are typical of the “sneaker net” communication scenario found in many SMEs. Processes and tasks are described verbally. Job orders are delivered by hand throughout the shop floor. If paper documentation exists, it is often incomplete or out of date.

Magdic personnel felt that electronic data display tools could enhance data management, improve documentation, lead to parallel job processing, and ultimately help to reduce product cycle time. At the same time, these improvements would help Magdic to enhance its position as a market leader for rapid product design and delivery. IET consultants subsequently matched Magdic’s improvement need with the technology adoption research being performed by the TIDE Program.

1.3 Gentile Manufacturing Company

Gentile Manufacturing Company, Incorporated designs and manufactures sophisticated parts and assemblies. Gentile had all of Magdic’s challenges plus the following unique issues:

- Cost tracking was manual and not progressive.
- The quotation process was lengthy and difficult.
- A key client required real-time visibility of work status.
- The raw material inventory was not tracked.

Most importantly, Gentile’s largest customers were demanding that the company conduct business in a “pure” electronic format. The ability to electronically manage and integrate business and operational data would enable Gentile to respond to this demand.

1.4 Project Motivation

From the perspective of the TIDE Program, the ability to help two different companies adopt a common technology solution had a number of advantages. It would allow the TIDE Program to increase the amount of technology adoption data gathered while leveraging program resources. It would enable TIDE personnel to acquire information about two different types of manufacturing businesses. (Magdic specializes in low-volume, custom products. Gentile was a higher volume job

shop.) Finally, it would enable the TIDE Program to measure the impact of the software on both businesses going forward.

1.5 Project Scope

As initially conceived, the effort to document the process and benefits of adopting a manufacturing execution system (MES) would be conducted in three phases: Discovery and Planning; System Implementation; and System Analysis and Publication. However, shortly after completing the Discovery and Planning Phase, Gentile lost a large customer. That loss along with continued weakness in the metalworking market forced the company to reorganize its business. As a result, Gentile opted to not continue with the implementation phase of the project. Magdic Precision Tooling implemented the software technology that was selected. Magdic's implementation effort will be documented in a future technical note.

The remainder of this paper describes the specification and selection effort, and presents lessons learned to help other SMEs streamline their technology selection efforts.

2 Case Study

During the Discovery and Planning Phase, TIDE, Magdic, and Gentile personnel

1. performed a needs assessment and business case analysis
2. established a selection team and selection process
    a. determined prospective COTS solutions and compared them to system requirements
    b. demonstrated products and selected the appropriate software and hardware
    c. procured products

2.1 Needs Assessment and Business Case Development

To participate in the TIDE Program, Magdic submitted a technology adoption proposal. TIDE personnel reviewed the proposal, compared the proposal to Magdic's growth strategies, and evaluated Magdic's ability to implement the proposal. Gentile was introduced to the TIDE Program through the TIDE workshop "Introduction to Ecommerce for SMEs" conducted in December of 2001.

In the case of Magdic Precision Tooling, consultants from the Duquesne University IET had previously helped Magdic to implement a series of business process improvement activities. These changes resulted in a 20% increase in capacity without an increase in overhead. Magdic's strategy was to continue improving workflow to further reduce delivery times, enhance customer service, and obtain a competitive advantage. The company wanted help implementing a computer-based system for controlling job information. That system would allow Magdic personnel to

- scan and store drawings electronically
- enter and save job information with electronic order files
- display drawings along with the latest changes at each machine
- retrieve archived job files
- integrate engineering data with electronic order information

The consultant from the Duquesne University IET helped Magdic develop a business case. Based on an investment of $70K, company officials predicted a 10% increase in capacity and a 30% reduction in cycle time on new tool sets, resulting in a capacity to add $200K in new sales annually. Magdic presented this business case in its proposal.

After reviewing Magdic's proposal, TIDE personnel recommended that Magdic expand it to cover an integrated MES that would provide the desired capabilities while linking accounting, billing, and other front-office functions. It would also enable customers to review the status of their orders in real time. When fully implemented, the MES could help Magdic to establish a virtually paperless manufacturing environment.

In the case of Gentile manufacturing, three customers had asked the company to set up and maintain electronic Web portals. TIDE staff members invited experts from NIST to explore the possibility of a one-to-many portal translator or some level of automation to assist in the maintenance of these portals. While some one-to-many portal automation was possible, NIST specialists concluded that Gentile lacked the basic manufacturing execution software needed to automate a portal translation. An MES could provide that capability. In addition, Gentile had an opportunity to take over the renewal parts manufacturing business for another company. This activity also would require an MES to manage the volume of business. While no formal business plan was developed, the new business-forcing function justified Gentile's interest.

2.2 Establish Selection Team and Selection Process

In the next step, TIDE staff members worked with Magdic and Gentile personnel to identify roles and responsibilities for participants and to develop a process for software selection. Based on their experience in analyzing and specifying COTS systems, TIDE specialists suggested using the PECA methodology.[2] PECA was jointly developed by the National Research Council Canada and the Carnegie Mellon® Software Engineering Institute (SEI) to evaluate COTS software, document the factors involved, and record the decision-making process.

Initially, the TIDE specialists proposed that Magdic and Gentile employees form a joint selection team. TIDE staff members would train team members on the PECA process and document their efforts. However, the lack of time and available SME personnel forced the TIDE team to change the strategy. Instead of training a software evaluation team, TIDE members ended up serving on it. Selection team members included Charles Buhman, Bill Anderson, and Grace Lewis from the SEI;[3] Todd Sterlitz, Vice-President, Gentile Manufacturing Co.; Joe Magdic, President, Magdic Precision Tooling; and Simon Frechette, NIST.

In its first activity, the team tried to define the goals and scope of evaluation. The team struggled with "scope" verses "goal" semantics, wasting time in the process. Eventually, the team agreed on the following:

> Scope: Evaluate a small set of software packages, hardware, and infrastructure to support shop floor control, visualization, and a paperless, Internet-enabled environment.

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[2] PECA is a COTS selection methodology. The name is taken from the first letter of each of the process steps: Plan, Establish criteria, Collect data, and Analyze data.

[3] This touches on a fundamental difficulty with this type of research: participation verses observation. It is difficult to draw conclusions about how large a good team must be. In this case, TIDE staff members felt compelled to join to provide needed mass. For their part, the SMEs preferred buying subject matter expertise, rather than receiving training or facilitation.

> Goal: Select software that satisfies the needs of two small manufacturers and considers the shop floor environment, stakeholders' needs, ecommerce, shop floor visualization, and collaboration capability.

These statements are not significantly different. The teams suggests that the scope and goals must be precisely defined and clearly differentiated to avoid wasting time on semantics.[4]

Next, the team identified a series of tasks and a schedule for completion. This too required discussion and negotiation. For example, SME managers Joe Magdic and Todd Sterlitz simply did not have the time to take advantage of external resources such as the SEI software demonstration laboratory. They also did not have time to travel across town to the SEI facility. And they needed to limit the time that they and their employees could commit to this effort. The time factor remained an issue throughout the demonstration project, and a number of activities were modified to expedite matters.

2.2.1 Software Requirements Specification

This task involved identifying the fundamental specifications of any MES. The team agreed on a number of fixed requirements. These included

- budgets for purchase and implementation
- limits on the training time and effort that the MES would require
- an ability to implement the system within time deadlines imposed by customers.

Additional fixed requirements stated that the selected system would have to

- be PC based
- use Windows NT/XP/2000
- be compatible with Peachtree software
- meet key customer criteria (e.g., electronic collaboration and ecommerce capabilities)
- support AutoCAD and Unigraphics packages

Early on, the team dropped the requirement for compatibility with Peachtree software because each candidate MES featured an internal accounting package.

Having identified an initial set of selection criteria, the team discussed the need to interview stakeholders from accounting, purchasing, engineering, quality, production, technology, shipping, and receiving. The goal was to solicit lower level requirements. In the end, however, only the accounting stakeholder was interviewed. Joe Magdic and Todd Sterlitz provided the additional input to save the

[4] *Goal* is a statement of the desired state. *Scope* is an agreement on boundary conditions. For example, if the Goal is to "make money," how ethically it is earned could be a scope issue. The authors suggest combining the two concepts into one statement, for example, "to make money in an ethical manner," to focus the discussion on the project and not semantics.

selection team valuable time. Joe and Todd were familiar with both manufacturing and business operations, and had previous experience implementing computer-based systems.

In general, the criteria covered four areas:

1. functionality
2. ability to integrate with legacy systems
3. adoptability
4. strength of the vendor

Under each area, the team listed specific requirements. For example, “adoptability” included having Windows conventions, being very intuitive, and having a short learning curve.

The team used a decision support tool to weigh and prioritize the requirements. The tool helped facilitate communication among team members. At the same time, it provided a yardstick to measure candidate MES packages, and also allowed the team to analyze the impact of decisions on candidate software packages. This “sensitivity analysis” feature became important later in the evaluation.

2.2.2 Comparing Alternative Software Packages

TIDE members from NIST investigated MES packages (see Appendix D) and CAD viewer packages [Stevens 03]. In addition, the selection team researched the Internet, reviewed trade publications, and informally polled SME employees and customers. Based on that input, the team developed a short list of four MES packages. Figure 1 illustrates the process they used to compare the packages.

The selection team interviewed candidate vendors for first-pass fit against the requirements. Each package appeared to meet the requirements. It became a matter of judgment as to how well, how easily, how quickly, and so forth, each package would perform. Furthermore, each vendor featured local support, a large base of installed systems, and an active user community.

Next, the team asked for product demonstrations. All the product vendors could provide interactive live demonstrations of their systems via Internet remote-session-viewing technology (WebEx™ in this case). The vendors ran their software on their local systems while the evaluation team watched live via the Internet. This eliminated one candidate MES; the team felt that the package did not fit the underlying make-to-order business process.

The selection team asked the remaining three candidate vendors to bid to a representative system. The three bids were compiled into a spreadsheet that grouped costs into equivalent categories. (See Table 2, page 56) The spreadsheet included one aspect of life-cycle cost (annual maintenance fees) to indicate operational cost.

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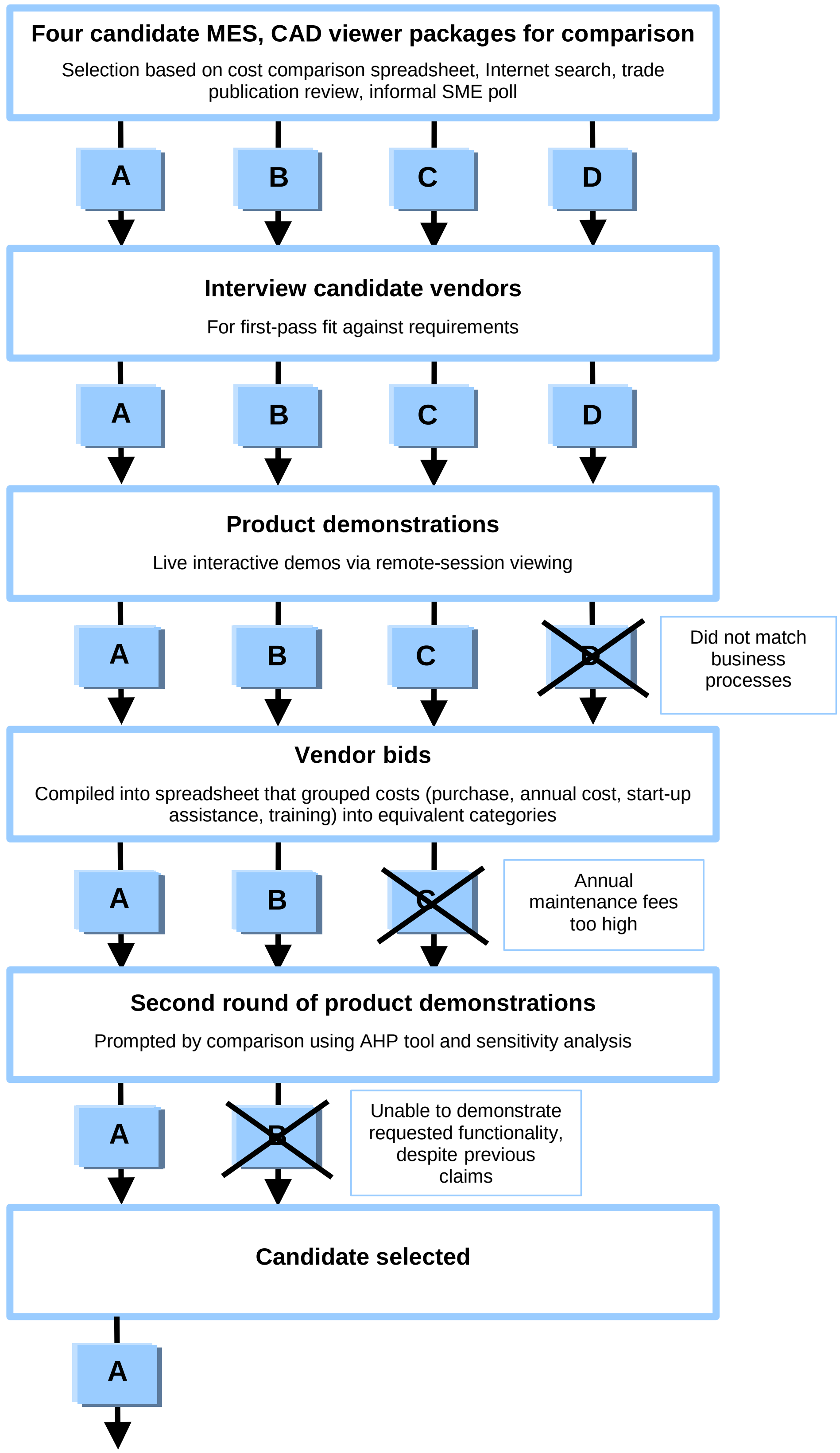

Figure 1: Comparing Alternate Software Packages

On the surface, the price between the high and low bids differed by less than seven percent. However, each vendor took a different path to reach the net price. One package carried a high list price that was deeply discounted and that served as the base against which a multiplier was applied to derive annual maintenance fees. In this first case, a high list price resulted in high annual maintenance fees ($5,400 per annum). The next package had a low list price, offered no discount, but used a high multiplier to derive the highest annual maintenance fees ($5,900 per annum). The third package had a list price in the middle that, when extended by the multiplier, produced the lowest annual maintenance fees ($2,600 per annum). When these recurring fees are considered over a few years they became a significant cost differentiator.

Another large variable was the cost and recommended levels of training and start-up assistance. The recommended packages varied from eight days of consulting plus two distance-learning classes for $11,300, six days of consulting at $7,200, and three days of consulting plus unlimited factory and Web-based training for $2,900.

The team cut the short list to two vendors and then checked those vendors' references. Using the Analytical Hierarchy Process (AHP) tool, a method for prioritizing decisions by incorporating relevant decision criteria, the team evaluated and compared the two vendors' software packages, and conducted a sensitivity analysis. (See Appendix A.) That analysis raised questions about whether either vendor's package could provide paperless, shop floor control. This prompted the selection team to ask for a second round of demonstrations. One vendor was unable to demonstrate the requested functionality, despite earlier claims that the product's current version could provide it. As a result, that vendor—which had been the leading candidate—lost the selection team's confidence and the sale. The second vendor readily admitted that this functionality was new, and although the vendor was confident that the software could provide paperless shop floor control, the vendor could not provide a reference that could vouch for that functionality; Magdic would be the first company to use it. The selection team appreciated that vendor's frankness and awarded it the contract.

The second set of demonstrations put the project behind schedule. However, it validated the benefit of the decision-support software and the structured COTS selection process (and verified the importance of demos to validate vendor claims).

2.2.3 Hardware Considerations

The implementation of an MES at Magdic required a system server, a large format scanner, and 10 terminals, one at each shop floor station. TIDE team members qualified hardware with the software vendor's and Magdic's concurrence. The TIDE-supplied hardware was purchased following SEI equipment guidelines, leveraging the university's purchasing agreements with an existing supplier. A mix of PCs and less expensive thin client workstations for the shop floor was purchased. Magdic purchased the Uninterruptible Power Supply (UPS), firewall, and network upgrades. A third-party network installer conducted a site survey and added several network drops and a cabinet to house the server and UPS.

2.2.4 Procurement and Licensing Issues

Procurement was much more complicated than originally anticipated. Despite the advice of vendors, certified Microsoft service representatives, and several experienced IT personnel, TIDE members were unable to discern the correct licensing requirements for the MES. Some products (the thin client terminals) required Certified Application Licenses. Others (the PC thin client emulators) came pre-licensed and were compatible with the terminal services environment. This was counterintuitive as the PCs (which have a stand-alone utility) came with an embedded license for the relatively less popular terminal services mode of operation, while the thin client terminals that only have utility in that mode required a separate license expenditure. This situation made projecting costs difficult. For example, the price of backup software tripled when its license incompatibility was finally resolved.

Furthermore, the maintenance contract provided by the MES vendor did not cover the integrated third-party packages. When one of these packages publicly announced feature updates, the selection team learned that it did not have the right to them. This raises a number of concerns.

- If a company purchases additional software licenses, which versions of the third-party software are included? Are these versions compatible?
- When the third party drops support of a given version, will the vendor take over?
- Who is responsible for purchasing updates? One would assume that the vendor would provide them under the maintenance agreement, but this was not the case.

The vendors' recommendation to purchase separate upgrades for the embedded third-party products generated a set of issues as well.

- If the SME buys upgrades separately, what level of coordination through the base vendor is available?
- Does the SME have the legal right (without harming its ability to get continued support from the base vendor) to integrate a revision of third-party software into the suite?
- Will the base vendor test and notify compatibility with future third-party revisions?
- Does the vendor supply a clear interface specification and instructions for installing the third-party software? Does the third party sanction the practice and procedure?

These are not just theoretical considerations. When the MES vendor had difficulty correcting a fault in a Web viewer portal, Magdic was willing to hire a third-party expert to remedy this fault. However the license restricted reverse engineering, derivative work, and remedial software repairs.

The solution is to establish a sound vendor relationship and to make sure company needs align with the vendor's target market, so that the vendor will want to address (or at least not ignore) customer requests.

2.2.5 Tools and Artifacts

As part of the software selection process, TIDE staff members applied a number of artifacts:

1) the specific hierarchical requirements tree that guided our product evaluation (see Appendix B).

2) a product dossier document that originated from the SEI Evolutionary Process for Integrating COTS-based systems (EPIC) [Albert 02]. A product dossier highlights a broad range of product evaluation issues (see Appendix C).
   For information on EPIC see <http://www.sei.cmu.edu/cbs>.

3) a cost comparison spreadsheet (see Appendix D).

4) a Manufacturing Execution Systems Product Survey, a product comparison matrix to aid in the software selection process (see Appendix E).

3 Lessons Learned

Budget and time limitations, a bewildering array of products, and lack of expertise can pose serious challenges to SMEs interested in adopting advanced software. The TIDE demonstration responded to these issues by emphasizing both preparation and process. The TIDE Program offers the following guidance for selecting advanced software technologies:

- *The size of the company will determine the type and amount of process required.* With fewer than 30 employees each, both Magdic and Gentile lacked the "mass" needed for the formal PECA methodology, forcing the process to adapt to the circumstances. However, the participants confirm that some structure was necessary to move the software selection process forward.
- *Team composition affects team tasking.* If the top decision makers are on the team, tasks that are motivated by upward communication and authority enablement are less important, if not unnecessary. Top-level management in a small enterprise is also well founded in comprehensive business process knowledge, reducing the discovery value of non-team stakeholder involvement. Stakeholder involvement becomes more motivated toward buy-in, training, and user acceptance.
- *Beware the PowerPoint® demonstration.* When a vendor switched from a live WebEx demonstration to a canned PowerPoint slide show, vaporware[5] was soon uncovered.
- *Decision-support software can be very helpful for software selection and other issues.* Properly implemented, decision-support software can help rank, compare, and clarify subjective issues, improve communications among different stakeholders, and facilitate the "what if" thinking that can lead to better decisions. However, the key to efficient use of this software is in limiting the scope of the investigation. Joe Magdic felt that an SME user, before using the software with confidence, would need someone to guide the process several times.
- *Stay in the vendor's sweet spot.* Finding a vendor that knows and is committed to the SME's business is critical. If the vendor is committed to the SME's market, the SME's issues will be market issues, creating more incentive for the vendor to resolve them. In addition, there may be other users who have already addressed common questions and issues.
- *SMEs must do their homework.* Often, vendors and prospective customers focus on the "bells and whistles" of the software, rather than the "nuts and bolts." Once that software

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5 *Vaporware* is defined as "products announced far in advance of any release (which may or may not actually take place)" [Jargon File 01].

has been installed, however, “nuts and bolts” features become very important. With so much on the line, SMEs need to learn as much as they can about the software’s capabilities, compatibilities, and processes. This requires the SME to do more than check references. Ideally, the SME should visit and interview customers who have similar operations, if possible. The SME should require the vendor to demonstrate typical or critical tasks.

- *Trainers should have domain expertise.* Pay attention to the trainer’s background and domain expertise before you engage. The accounting functions generally demand a deep background and understanding of accounting and how the software operates. This is not the same knowledge that it takes to understand the operations on the shop floor.
- *Vendors will sell flexibility.* The marketplace forces the vendor to be all things to all people (or at least a broad enough set of people to generate a market). But in reality the software will have “optimal use scenarios”—those ways of using the system that are tried and true. These are the scenarios that will have the lowest implementation risk; SMEs should find them and change their practices to take advantage of them.
- *The SME must be prepared to change.* COTS software is designed around a general business model. In most cases, the SME will have to modify its business and operational processes to use the software. To minimize the changes, the SME should select a package that fits its needs and follows the way it does business. Still, the SME should expect that changes will be necessary and desirable, especially if the software embodies improved or “industry best” practices. This also will keep the SME closer to the vendor’s sweet spot.
- *Ask questions and more questions.* Such questions include the following:
    - What 3rd party packages are bundled in the software suite and will the vendor support them?
    - What is involved in converting legacy data to work with the new system?
    - Does the vendor have a mechanism to educate employees about the optimal process scenarios to leverage his software?
    - Do you need editable versions of (and rights to use) the training materials, perhaps to generate your own process procedures?

4 Summary

Advanced software technologies can increase productivity and reduce costly errors. However, selecting the best software requires understanding a number of factors. The TIDE Program investigated these factors during the course of selecting MES software for two SMEs. The effort underscored the need for SMEs to

- understand their business and how the proposed software will support their firms' growth strategy
- use a process to understand requirements and correlate to capabilities
- scale the selection process to fit the organization
- involve experienced personnel (including outside decision support and technology adoption specialists if necessary) to clarify issues and identify pitfalls
- investigate vendors and their products from a variety of perspectives

Appendix A: Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was proposed by Saaty over 20 years ago and is a widely used technique for multi-attribute decision making [Saaty 80]. It is a method of prioritizing decisions by incorporating relevant decision criteria.[6] This prioritization achieved through pair-wise comparisons of competing objectives and through making subjective judgments. This results in a ratio scale of relative values. The AHP is carried out in two phases. In the Design Phase, a criteria hierarchy is set up. In the Evaluation Phase, pair-wise comparisons are used to evaluate alternatives. Figure 2 on the next page illustrates the major steps involved in an AHP facilitated evaluation.

Structuring the Evaluation

The initial step in using the AHP tool is structuring the decision to be made. In this case, the method was used to evaluate and eventually recommend a COTS product.

Criteria Development

Criteria are statements or conditions that serve to validate that a requirement has been met. They help to translate the subjective to a more objective perspective. Criteria development can be a layered process that repeatedly asks “Why?” or “What does that mean?” This recursive decomposition must be used with caution however; it is very easy to quickly build a model that becomes cumbersome in future steps.

User Requirements Definition

The first step is to gather key stakeholders to brainstorm user requirements. Figure 3 shows the beginning steps of establishing user requirements for a COTS software product. Three different requirements have been identified:

1. All functionality is provided.

2. Product integrates with legacy systems.

3. Product is “adoptable” by the organization.

6 This is a generic description of the AHP process applied to software resolution. Appendix B reflects the specific requirements matrix that was used in this case.

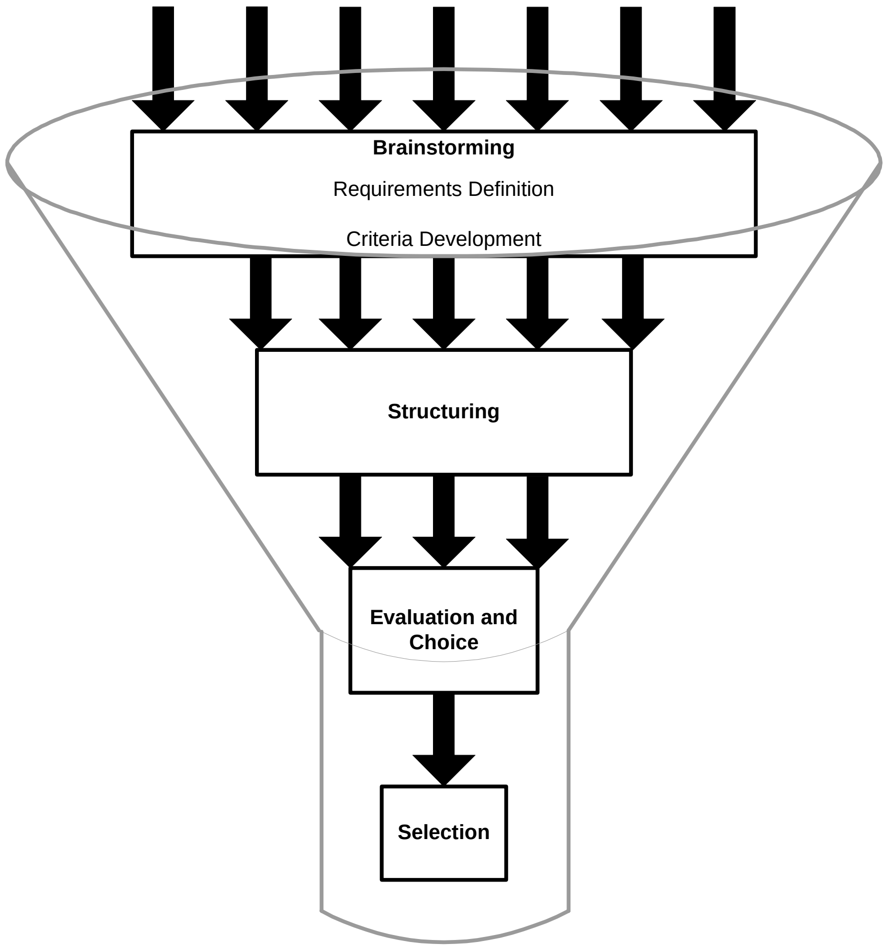

Figure 2: AHP Methodology of Evaluation

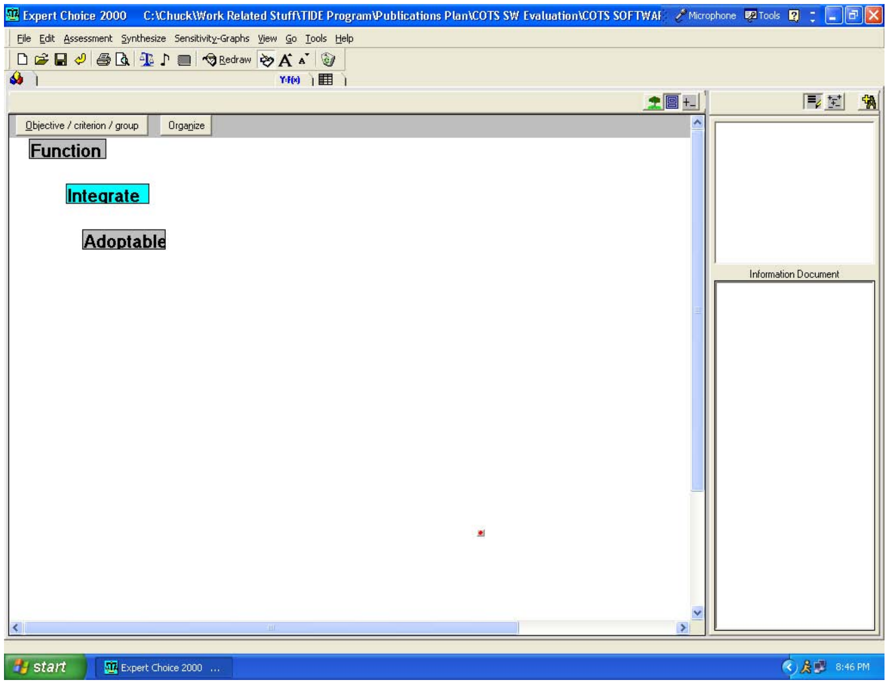

Figure 3: AHP Tool Capturing Initial User Requirements

User requirements definition requires more than brainstorming a wish list of features and functions. Users' needs and wants must be identified and structured to facilitate evaluating alternatives. AHP-based tools provide a consistent and repeatable process for translating requirements into evaluation criteria.

Clustering

One of the more time- and labor-intensive aspects of the evaluation process is establishing a list of criteria in such a manner that all requirements can be clearly understood and communicated to stakeholders and decision makers. This task is aided by "clustering"—grouping requirements into "theme categories" that will become the evaluation criteria hierarchy. Figure 4 shows the three previously mentioned requirements (functionality, integrability and adoptability) as the theme categories containing nine different evaluation criteria.

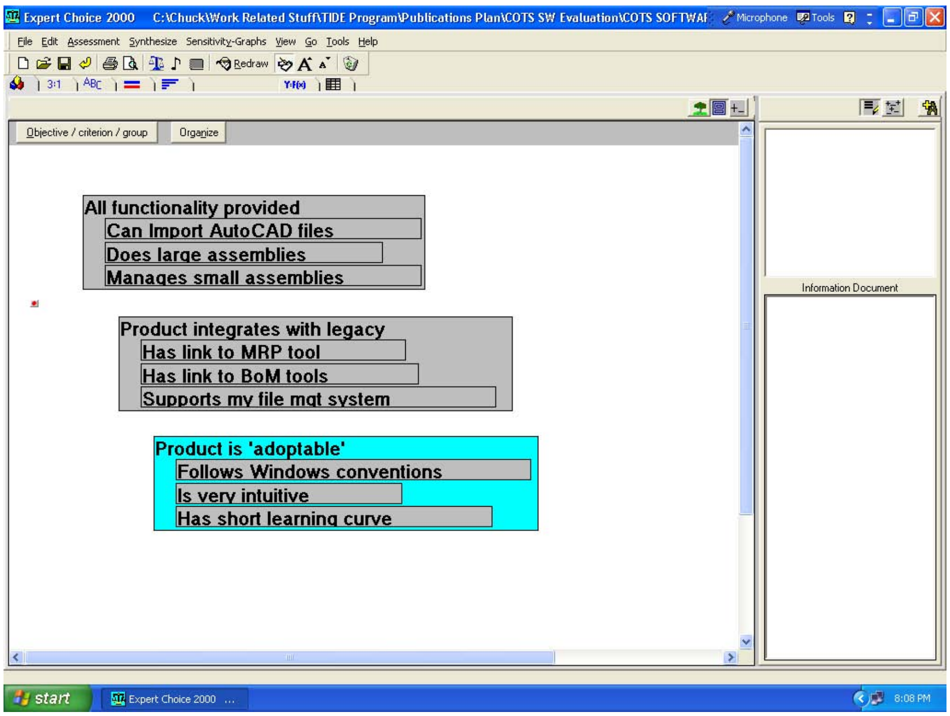

Figure 4: Using Clustering to Identify Criteria

Identifying Alternatives

Once high-level user requirements and related evaluation criteria have been established, viable alternative COTS products can be identified. At this stage, the evaluation team will frequently incorporate a user requirement involving the strength of the company. Figure 5 shows how an AHP tool handles the list of alternatives (COTS1, COTS2, COTS3, and COTS4). It also shows the user requirement "company strength" along with four associated evaluation criteria.

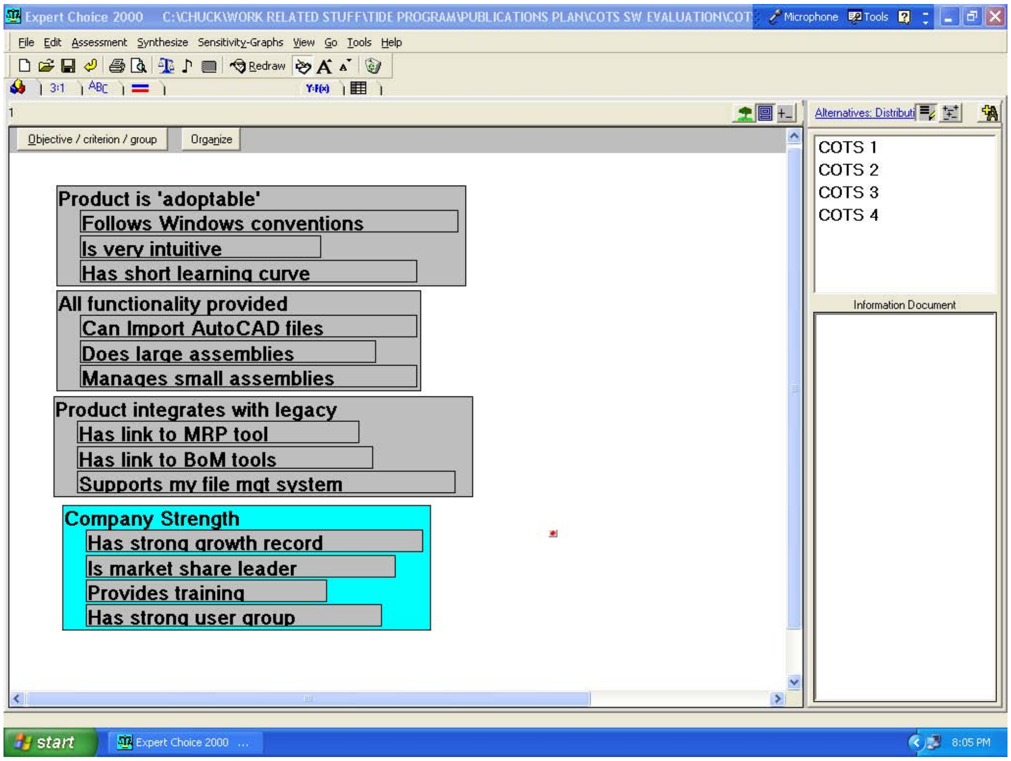

Figure 5: Adding Alternatives and Developer-Related Requirements

Establishing the Evaluation Hierarchy

Once the alternatives have been identified and a sufficient number of criteria established, the AHP tool can automatically create the evaluation hierarchy. At this stage all criteria are equal; no attempt has been made to establish weights or priorities.

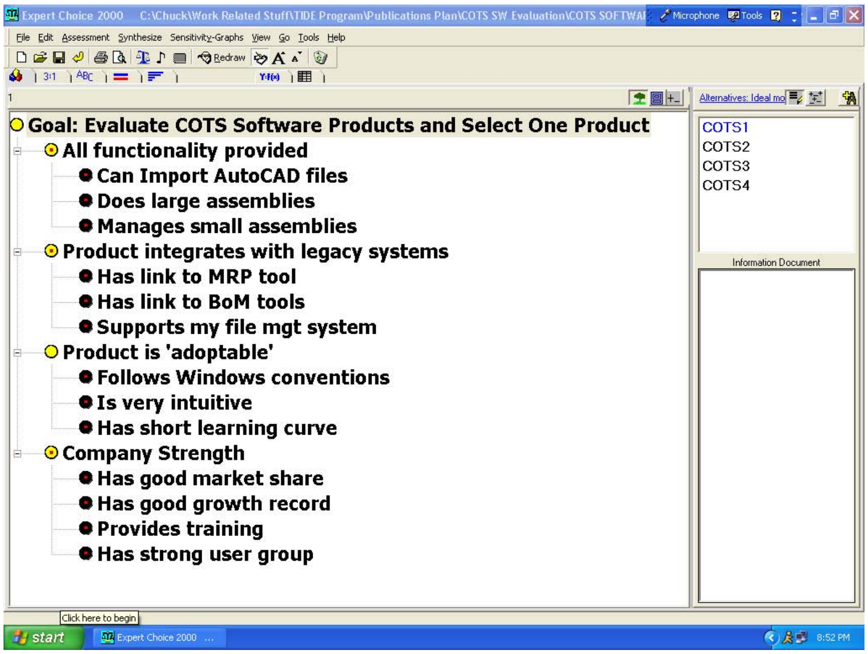

Figure 6: The Initial Hierarchy for Evaluation

Some criteria (e.g., “Has short learning curve”) may require additional definition or another level of refinement. The following screen shows the addition of another “branch” to the “adoptable” portion of the hierarchy.

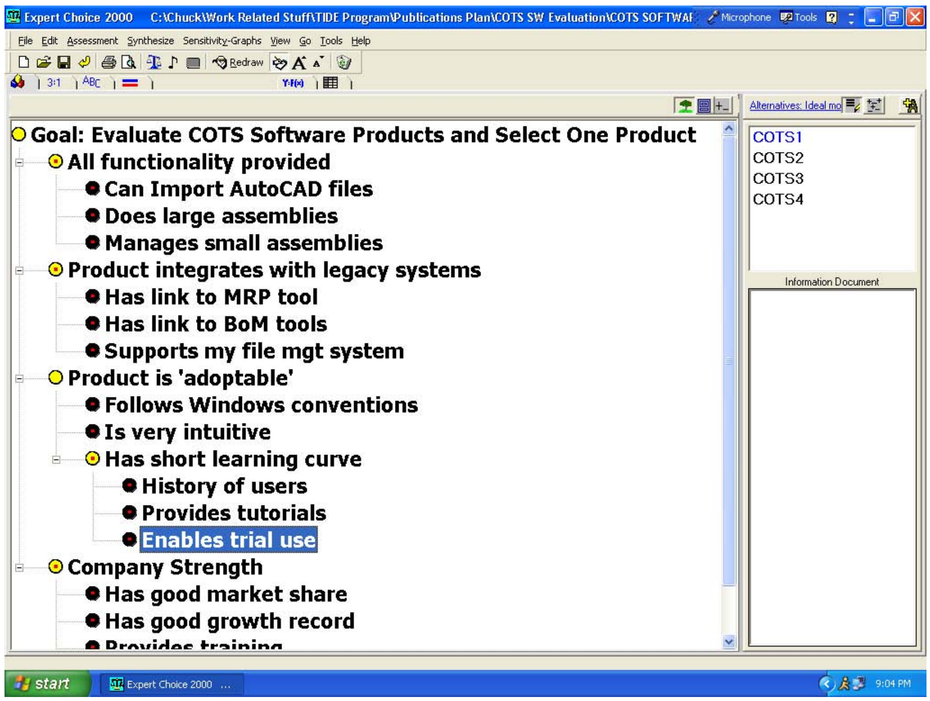

Figure 7:   Addition of “Branch” to Improve Criteria Definition

Deriving Requirement and Criteria Weights

Once requirements and criteria have been identified, the team can establish priorities for each. The process is established through the mechanism of pair-wise comparisons in which each requirement and criterion is compared against its “siblings” within the evaluation hierarchy. In the example, the high-level requirements that will be compared are

- degree of functionality
- ease of integration
- ease of adoption
- degree of company strength

Similarly, within the theme category (requirement) “adoptable,” several criteria will be compared:

- follows Windows conventions
- is very intuitive
- has a short learning curve

In this example, a “verbal” approach has been used to compare the top-level requirements. The following screen capture shows the comparison matrix between the four user requirement categories. Initial comparisons have been made, and normalized weights have been assigned by the AHP tool. Note that the tool provides a histogram to show the relative importance of each requirement as the process unfolds.

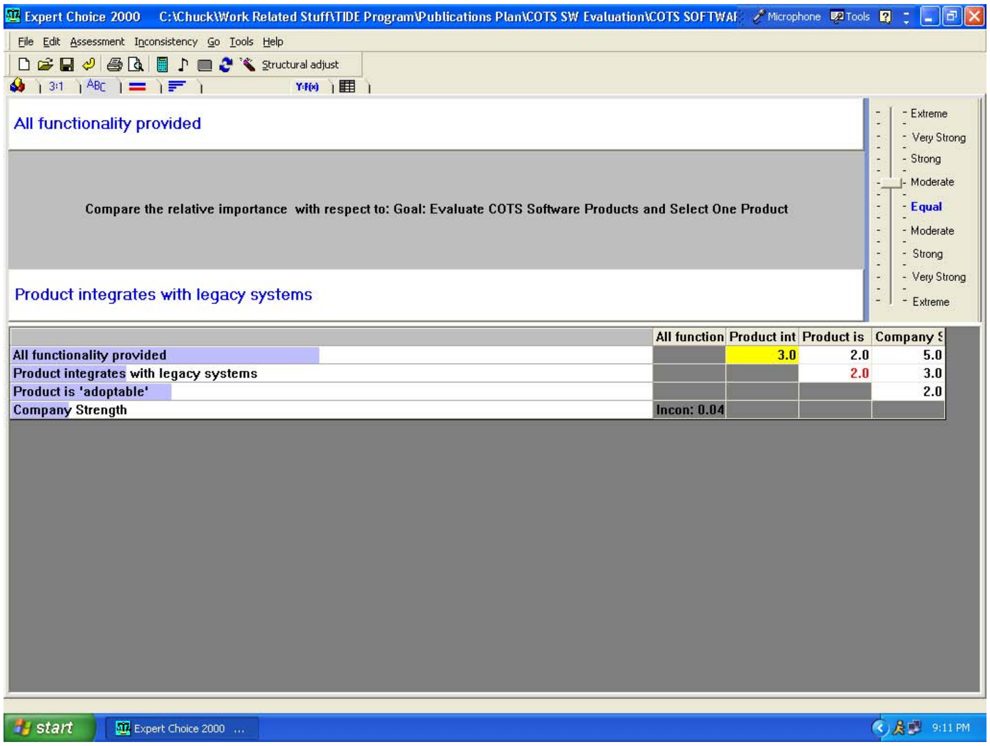

Figure 8: Pair-Wise Comparison of High-Level Requirements

This pair-wise approach allows evaluators to compare tangibles or intangibles on a reliable scale. Each evaluator expresses an opinion and all individual judgments are collected and aggregated into a group judgment.

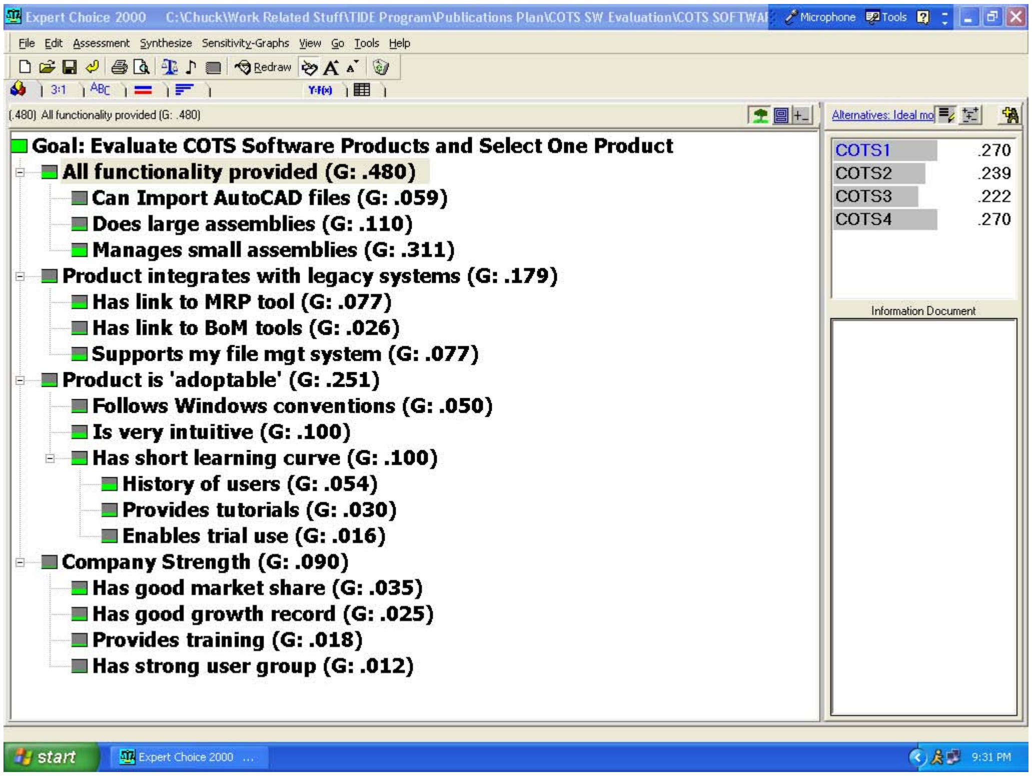

Figure 9: Evaluation at the Completion of All Comparisons

At this stage the evaluation team has established weights for each of the criteria and expressed its opinion of the four COTS software packages and their ability to satisfy the different criteria.

The high-level requirements have been weighted and sorted. Their relative importance is illustrated using bar graphs. In this example, the evaluation team deemed “functionality” as by far the most important requirement. It has a normalized score of .480, nearly half the total assessment of utility. In other words, the team felt that functionality was nearly as important as all other requirements combined.

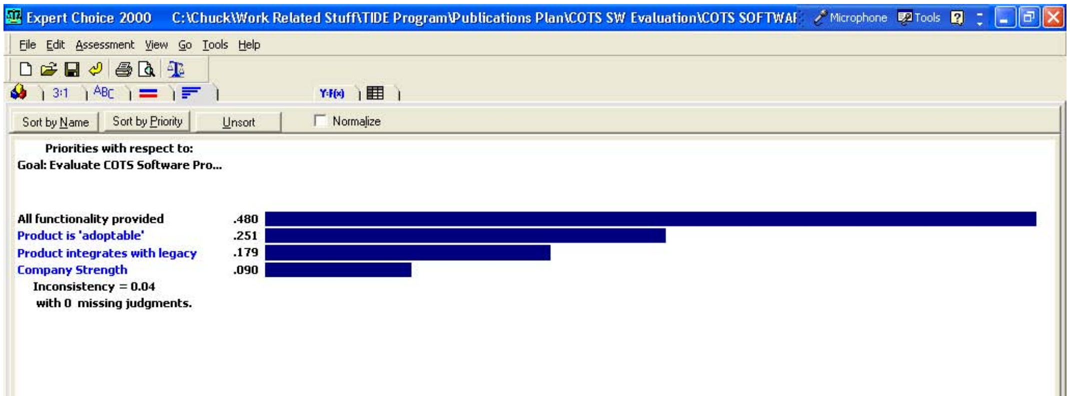

Figure 10: Relative Importance of High-Level Requirements

At this stage, each team member will understand how other team members feel about the requirements and criteria and how their different perspectives influence the evaluation. Further, the team members will see where they agree. Effort can therefore be focused on areas of disagreement or where there are points of uncertainty or misunderstanding.

Sensitivity Analysis

Because the evaluation process is inherently uncertain, it must accommodate sensitivity analysis, which determines what influence each assumption has on the recommendation. At each level of the hierarchy, the evaluation team can see the relative importance of its criteria (left-hand pane below). The team can also dynamically change these relative weights and view the outcome (right-hand pane).

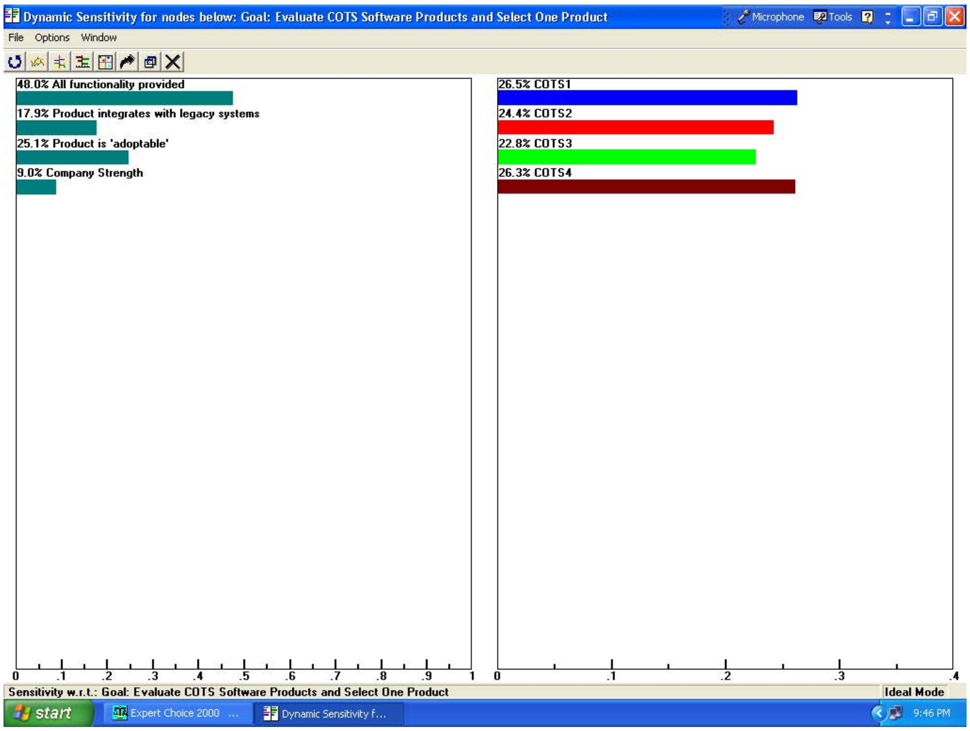

Figure 11: Dynamic Sensitivity Analysis

“What If?” Scenarios

An important use of dynamic sensitivity analysis is in “what if” scenarios, which test the robustness of the recommendation under a variety of different assumptions. Since a number of the criteria in a typical evaluation may be quantifiable, a sensitivity analysis can show the extent to which the recommendation might change if an assumption were altered.

In the example, products COTS1 and COTS4 have virtually the same ratings (.265 vs. .263). Increasing the importance of “functionality” does not cause the relative scores of COTS1 and COTS4 to change. The recommendation is very insensitive along the dimension of functionality. Similarly, the importance score of “integration” must substantially increase before it changes the rank of the products. However, increasing the importance of adoptability changes the recommendation from COTS1 to COTS4. Increasing the importance of “company strength” only serves to increase the score of the leader, COTS1.

By conducting this type of sensitivity analysis, the evaluation team can focus on issues that can potentially change the recommendation: the criteria in the “adoptability” requirement. Examining the “adoptability” branch in detail provides insight into the recommendation. As the following screen capture illustrates, the team felt that COTS4 was significantly more intuitive than the other products. This rating was sufficient to award COTS4 the highest rank in this dimension. By highlighting these criteria, the team can double-check the reasons for the initial ratings to make sure that all team members are comfortable with the conclusions.

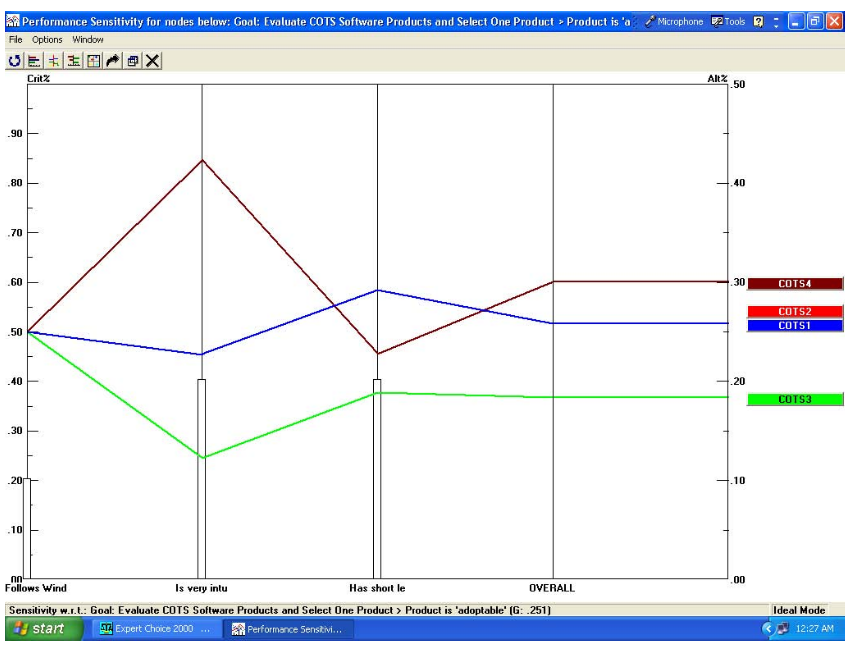

Figure 12: Closer Examination of the “Adoptability” Criteria

Building Consensus

As with criteria comparisons, the evaluation team sees where it agrees and disagrees on a product evaluation. Where there is no disagreement on where the decision is insensitive to changes in assumptions, there is no benefit in protracted discussion. Where there is disagreement or where the decision can change with a modest change in assumptions, it is worth the team’s time to scrutinize. Building a consensus within the evaluation team and communicating such to the stakeholders is arguably the most valuable aspect of this methodology.

Appendix B: AHP Requirements Matrix

The following pages contain the specific AHP requirements matrix that was generated on this project. This matrix was formatted for use as a checklist and note template for use during product demonstrations, to aid in Product Management (PM) tool selection.

Table 1: User Requirements Review of Shop Control Software

score	Goal: Select a PM Tool	Comments
	1. Production Management Functionality Provide the necessary production management functions that meet the needs of a typical small job shop.	
	1.1 *Engineering Definition Process Designer*	
	1.1.1 Engineering Change Notification	
	1.1.2 Accommodates legacy definitions	
	1.1.3 Travelers	
	1.1.4 Routing	
	1.1.5 Bill of Material Mgmt.	
	1.2 *Inventory Mgmt*.	
	1.2.1 Can write off obsolete items	
	1.2.2 Track finished goods inventory	
	1.2.3 Track work in process inventory	
	1.2.4 Inventory Link to Orders	
	1.2.5 Different Units	

score	Goal: Select a PM Tool	Comments
	1.3 *Data Collection and Dissemination*	
	1.3.1 CAD Interface Tool can view AUTOCAD, Unigraphics, or other popular CAD tools.	
	1.3.2 Customer-Supplied Bar Code Tool can import or interface with customer-supplied bar codes.	
	1.3.3 Access linked drawings and text documents.	
	1.3.4 Information is collected and validated automatically to improve accuracy	
	1.3.5 Collect Labor Time.	
	1.3.6 Bar codes built into forms and reports	
	1.4 *Mgr.'s "Desktop"*	
	1.4.1 Reports	
	1.4.1.1 Standard Tools Define a report using applications such as Crystal Report, Access, Word, or Excel.	
	1.4.1.2 Report Templates Tool comes with a portfolio of standard reports that meet most of the company's needs.	
	1.4.2 Executive Information System Provides managers with fast, easy executive-level insight into important production information.	
	1.4.2.1 Supplier management	
	1.4.2.2 Planning Tool enables user to do rough-cut capacity planning, material planning, "what if" planning, budgeting, and so forth.	
	1.4.3 Traceability	

score	Goal: Select a PM Tool	Comments
	1.4.4 Quality Management Tool has standard statistical process control (SPC) functions.	
	1.4.5 Keyword Search Can conduct a keyword search across all data files	
	1.4.6 Identification Opportunities Facilitates identification (ID) of opportunities to make changes to production (paths, schedules, etc.) that will facilitate better factory throughput	
	1.4.7 Alarms System alarms warn of certain critical situations.	
	1.4.8 Proactive Information Management Proactive management of information flow to customers, vendors, and others	
	1.5 *Integrated Business Functionality*	
	1.5.1 Integrated Accounting	
	1.5.2 Integrated Purchasing	
	1.5.2.1 Blanket- Order Mgmt.	
	1.5.2.2 Alternate Vendor	
	1.5.2.3 Receive to stock or to job	
	1.6 *Collaboration Portal* Has the ability to publish information for use by customers and/or vendors, providing insight into production	
	1.6.1 eBusiness Interface Tool supports eBusiness interfaces with customers.	
	1.6.2 External Viewer Provides a Web-enabled viewer (browser based) to enable either customer or vendors to check on orders.	

score	Goal: Select a PM Tool	Comments
	1.6.3 Event Management	
	1.7 ***Order Management***	
	1.7.1 Control Material Effectively	
	1.7.2 Search Can search for orders based on a variety of criteria	
	1.7.3 Order Acknowledgement	
	1.7.4 Process Orders Efficiently	
	1.8 ***Schedule Realistically***	
	1.8.1 Basic Infinite Scheduling	
	1.8.2 Advanced Scheduling Finite and "what if" scheduling capabilities	
	1.9 ***Quote accurately and easily*** The tool supports easy development of estimates and quotes	
	1.9.1 Quote Tracking Provides a follow-up reminder and the ability to save and archive old quotes.	
	1.9.2 Routers and Material Sheets Development of quotation results in the development of routers/travelers for the proposed job.	
	1.9.3 Inventory Link Quote systems in linked-to inventory.	
	1.9.4 Same-as-Except System supports use of previous quotes or jobs to develop new estimates or quotations.	
	1.9.5 Estimating Can easily develop estimates for new proposals	

score	Goal: Select a PM Tool		Comments
	2	**Integrate** Integrates well with other elements (software and hardware) of the SME's system	
	2.1	***Open Database Connectivity (ODBC)***	
	2.2	***Other Legacy Systems*** Can easily integrate with existing systems.	
	3	**Sustainable** New software tools and process can be adequately sustained by the SMEs.	
	3.1	***Company Strength*** The company that developed the software is strong, and will be able to support the product and produce the appropriate upgrades and enhancements, and provide long-term support for this product.	
	3.1.1.	**Profitability**	
	3.1.2	**Market Share**	
	3.1.3	**Installed Base**	
	3.2	***Extensible*** The developer has plans for future additional features or attributes to keep up with evolving needs of the manufacturer.	
	3.3	***Scalability*** The product can "grow" to accommodate additional users and a greater number of files.	
	3.4	***Supported Evolution*** The product will be supported by the developer with planned enhancements and upgrades to keep it technically current.	
	3.5	***Support***	

score	Goal: Select a PM Tool	Comments
	3.5.1 Documentation Tool has documentation that adequately enables the users to sustain the system.	
	3.5.2 Help Desk	
	3.5.3 User Groups	
	3.5.4 Local Support Tool has local technical support for on-site assistance.	
	4 Reliable New software tool is reliable.	
	4.1 ***Easy Fixes*** Failures can be fixed by the SME's personnel.	
	4.2 ***Failure Consequences*** If the system fails, it does so in a non-catastrophic way (data is not lost, the failure does not bring down other elements of the environment, etc.).	
	4.3 ***MTTR*** The mean time to repair any failure is adequately short.	
	4.4 ***MTBF*** The software has an adequate mean time between failures.	
	5 Adoptable	
	5.1 ***Good Graphic User Interface (GUI)***	
	5.2 ***Implementation*** Can be installed and ready for use in a weekend	
	5.3 ***Tailorable and Flexible*** The tool is easy to tailor, using standard templates, to meet the unique needs of most users.	

score	Goal: Select a PM Tool	Comments
	5.4 ***Software tool is intuitive.***	
	5.5 ***Training***	
	6 **Operating Environment**	
	6.1 ***SQL or other "easy" database***	
	6.2 ***Object Linking Embedding Database (OLE DB), Java, or Distributed Component Object Model (DCOM)***	
	6.3 ***ODBC Compliant***	
	6.4 ***Windows NT, XP, or 2000***	
	6.5 ***PC Based***	

Appendix C: Product Dossier Guidelines

By Edwin Morris[7]

Overview

The product dossier artifact captures all the information regarding a single COTS product, including characteristics of the vendor; product architecture and functional capabilities; standards supported; required hardware and software configurations; nonfunctional characteristics such as usability, supportability, reliability, interoperability, portability, and scalability; quality of documentation; costs; and licenses. A Product Dossier is created when the product is introduced and updated as appropriate.

Purpose of Captured Information

The product dossier artifact accumulates and organizes information sufficient to record

- the history of contacts with the vendor regarding the product
- the history of consideration and use of the product
- raw (unfiltered) information about a product and product vendor gathered directly from the vendor (documentation, claims, price lists, demonstration versions, etc.), and from third parties (such correspondence and reviews by other users, trade journal articles, business/financial analysis, etc.)
- processed (filtered) data obtained during consideration of a product including the results of investigations into the product and vendor, information describing the exact configuration of the product evaluated, and data gathered during evaluation activities and benchmarking
- the analysis of the product and vendor, including product/vendor strengths, weaknesses, related products and ensembles, and architecture or usage constraints identified during evaluation
- the history, rationale, and specific activities for customization and tailoring of the product
- the history, rationale, and specific activities for integration of the product
- the history of version releases
- the history and rationale for upgrade decisions and certification activities

[7] These guidelines by Edwin Morris of the SEI first appeared in *Evolutionary Process for Integrating COTS-based systems (EPIC)* [Albert 02]. Introductory text that is only relevant to the EPIC process has been omitted.

Information Needed

The goal for populating the Product Dossier is to capture information sufficient to select (or rule out) a specific product version, to maintain data about the architectural, design, implementation and testing ramifications of using the product, to transition necessary skills to stakeholders (such as maintainers and end users), and to support the maintenance/evolution process of the product in the system.

The categories of information maintained within the Product Dossier are extensive. Some of this information is developed to support the selection of the product. Other information is developed as the product is incorporated and maintained in the system. Thus, a Product Dossier is a living document that represents the state of knowledge about a product during the time it is considered, used in, and maintained for the system. Examples of the categories of information that are maintained in a Product Dossier are identified below. The type and degree of information maintained for each category will depend on a number of factors, including the characteristics of the product, the stage in product selection and use, and how the product is or will be used in the system. In addition to example categories, sample questions that illuminate the intent of the categories are provided.

Vendor Characteristics

Organizational stability	• Has the organization existed in its present form for a suitable period to indicate that it is stable?
Financial stability	• Is the organization making money? • What are the financial trends?
Nationality	• Is the organization based in the U.S. or a nation allied with the U.S.?
Ease of access	• Is there sufficient access to the organization for answering technical and business questions?
Independence	• Does the vendor make independent decisions, or is it (effectively) controlled by another organization? • Are the goals and directions of the controlling organization appropriate for the needs of the target system?
Reputation	• Does the organization have a reputation for quality? • Is delivery timely? • Is the organization responsive to customers?

Support infrastructure	•	Does the organization offer local offices, hotlines, installation, and integration support?
Engineering approach	•	Is the engineering approach used by the organization appropriate and compatible with the customer's expectations and needs?
Maintenance approach	•	Is the maintenance approach appropriate and compatible?
History	•	What is the history of the organization? Where did the organization come from and how did it come to market this product?

Basic Product Characteristics

Shipment dates	•	When was the product first made available to customers?
Product stability	•	What is the release history of the product?
	•	What types of changes were made for various releases?
Install base	•	How many copies of the product are in use?
	•	How many organizations use the product?
	•	Are these organizations similar to the target organization?
	•	Can the use of the product by these organizations be verified (i.e., not marketing hype or shelfware)?
Customer references	•	What customer references are available?
	•	How do these customers use the product, when did they take delivery, how many copies of the product do they use, and how many users are supported?
	•	What are their impressions of the vendor, product, support, and so forth?
	•	Is the use of the product by these customers similar to the anticipated use of the target organization?

End-of-life plans	• What phase-out or end-of-life planning is being considered by the vendor for the product? • When is a phase-out or end of life planned? • What will the upgrade path be? • What will this upgrade require of users? • Are any plans documented and available to customers?
Availability of training	• What training is available for the product, when and where is it offered, and is it tailored to the customers' needs? • For what groups of stakeholders (system personnel, maintainers, end users, etc.) is training available? • Are any third parties providing training?
Access to hotline	• During what hours of operation is a hotline available? • What types of support are available? • Are hotline calls fielded domestically? • Are there appropriate capabilities to maintain required security?
Consultants	• Are vendor-sanctioned consultants available? • Are third-party consultants available? • What is the availability and cost for consulting?
Delivery method	• What media is used for delivery of the product and product upgrades (tape, CD, internet, etc.)?

Standards

DoD standards	• What Department of Defense (DoD)-specific standards are supported?
Industry standards	• What general industry standards are supported? • What standards body is responsible for the standard?

- How do organizations join or influence the direction of the standard?
- Is the standard widely supported?
- Do one or more organizations have extensive control over the standard?
- What is the release history of the standard?
- How can contact be made with the group or committee responsible for the standard?

Organizational

- Does the product and vendor meet special standards, procedures, and protocols required by the target organization?

Completeness

- Does the product implement a subset of the standard, the complete standard, or a superset of the standard?
- What are the plans for updates or enhancements to subsequent versions of the standard?

Confidence

- How is standards compliance verified?

Hardware

Configuration

- What are the minimal, recommended, and maximum hardware configurations (computers, processors, memory, disk, bus, peripherals, etc.)?
- What incremental steps can be made in hardware to increase the performance and storage capacity of the system?
- Does the required hardware configuration conflict with that of any other system with which the product must interact or be collocated?
- Is a special or different development, testing, or support environment required?

Communications

- What communications infrastructure is required?
- What bandwidth?
- What configuration?

Hardware compatibility	• Are there any known compatibility problems between the product and hardware components?
Accuracy	• Is the accuracy of all hardware components within the required configuration appropriate for my needs?
Security	• Is the security of all hardware components within the required configuration appropriate for my needs?
Reliability	• Is the reliability of all hardware components within the required configuration appropriate for my needs?
Vendor characteristics	• Are vendor characteristics for all hardware components within the required configuration appropriate for my needs?
Product characteristics	• Are the characteristics for all hardware components within the required configuration appropriate for my needs?
Upgrade	• How is the upgrade of a hardware component tied to the upgrade of the product?
	• How long after an upgrade of hardware is a product upgrade generally available?
	• How long are old versions of hardware supported by the product?

Software

Operating system	• What operating system(s) are required (including versions)?
	• Are the performance and size characteristics appropriate for the needs of the target system?
	• What mechanisms exist to identify and resolve problems related to the interface between the operating system and the product?
	• Who is responsible for identifying and resolving the problem?
Communications	• What communications support is required (including versions)?
	• Are alternate communications capabilities supported?
	• Are the performance and size characteristics appropriate for the

	needs of the target system?
	• What mechanisms exist to identify and resolve problems related to the interface between communications capability and the product?
	• Who is responsible for identifying and resolving those problems?
Database	• What database support is required (including versions)? Are alternate databases supported?
	• Are the performance and size characteristics of the supported database(s) appropriate for the needs of the target system?
	• What mechanisms exist to identify and resolve problems related to the interface between the database and the product?
	• Who is responsible for identifying and resolving those problems?
Related applications	• What other applications are required (including versions)?
	• Are there alternates for these applications?
	• Are the performance and size characteristics appropriate for the needs of the target system?
	• What mechanisms exist to identify and resolve problems related to the interface between the related applications and the product?
	• Who is responsible for identifying and resolving those problems?
Compatibility problems	• Are there any known compatibility problems between the product and any software components?
Accuracy	• Is the accuracy of all software components within the required configuration appropriate for the needs of the target system?
Security	• Is the security of all software components within the required configuration appropriate for the needs of the target system?
Reliability	• Is the reliability of all software components within the required configuration appropriate for the needs of the target system?
Vendor characteristics	• Are vendor characteristics for all software components within the required configuration appropriate for the needs of the target system?

Product characteristics	• Are the product characteristics for all software components within the required configuration appropriate for the needs of the target system?
Upgrade	• How is the upgrade of a software component tied to the upgrade of the product? • How long after an upgrade of software is a product upgrade generally available? • How long are old versions of software supported by the vendor?

Usability

Intended use and users	• Who are the intended users of the product? • For what use was it intended?
General operability	• How hard is the product to use?
Skill level required	• What skills are required by users?
Responsiveness	• What is the response time under a light load? Average load? Peak load? • Can response times be tuned or improved?
Robustness	• What is the mean time between failures for the product? • How does the product respond to erroneous input and operator error?
Help capabilities	• What help capabilities are available in the product?
Error assist/recovery	• How does the product assist users when they make a data input error? • How does the product support users in recovery from erroneous input?
Understandability	• Is the product easy to understand? • Are common usage paradigms employed?

Learnability	• How long will it take before employees will be proficient with the product?

Supportability

Dependencies	• Does the product make use of any component or capability provided by an organization other than the vendor? • To what extent does success of the product within the target system depend on these organizations? • How is failure of a component produced by another party handled? • How would subcontractors fair if subjected to the same evaluation scrutiny as the vendor?
Upward compatibility	• Have all versions of the product been upward compatible? • Which versions have not been and why? • What steps must be taken when a new release of a product must be installed?
Site installation support	• Who is responsible for installation of the product on-site? • Will the vendor install the product? • Is there extra cost for this service? • Can target organization personnel install the product? • What skills are required?
Site operation support	• Will the vendor provide personnel to support initial operations, perform standard maintenance, or diagnose errors? • Does the product indicate to users/operators when maintenance is necessary or an error has occurred?
Analyzability	• Does the product provide capabilities to analyze performance? • Locate problems or bugs? • If capabilities are not provided, how is this accomplished?

Replaceability	• If the product must be replaced with another commercial product, what changes would be necessary to the system? • What activities would be necessary for data migration?
Preventive maintenance	• Is periodic preventative maintenance required? • How frequently? • What activities are involved?
Special support	• Is a special or different development, testing, or support environment required? • What are the characteristics and components of that environment? • What tools are required or suggested?

Interoperability

Data model/format	• What data model and formats are employed by the product? • Are they published? • What standard are they based on? • What other products support the same data model/formats?
Support for data access	• What interfaces or techniques are available to access product data? • What effort is required to access product data? • Is the granularity of data access appropriate for the target system?
Support for control	• Can the product be invoked by other applications? How? • What is the granularity at which the product can be invoked? • Can other products control low-level functions that might be necessary in the integrated system (for example, commit to a change)? • Can the product invoke other applications? How?

	• What constraints are placed on these invocations? • How can the execution of the product and other components be synchronized? • What timing concerns may arise?
Infrastructure utilized	• What infrastructure is used to support the communication of messages, data, and control sequencing within the product? • Can the infrastructure be used by other system components to interact with the product?

Reliability

Test regimen	• How is testing performed by the vendor? • Are the results of testing independently verified? • Are test scripts and results available?
Type/frequency of faults	• What is the mean time between failures? • What is the frequency of different sorts of faults?
Recovery from faults	• What is the error-handling strategy? • Is there journaling of faults? • Are all faults trapped before the system panics?
Benchmarking	• Are reliability benchmarks available for the product? • Are any claims made about reliability?
Experience	• Do systems requiring similar reliability to the target system use the product? • Which ones?

Performance

Benchmarking	• Are performance benchmarks available for this product?

	• Are the results of these benchmarks suitable? • Do the benchmarks reflect a usage situation or pattern consistent with that expected of the product in the target system?
Time-related behavior	• Does the product exhibit appropriate time-related behavior (throughput, lack of deadlock, thread-safety, latency, etc.)? • Is there any potential for time-related interactions with other system components? Where? • Have these interactions been evaluated and determined to be within acceptable limits or risk levels?
Resource behavior	• Does the product make appropriate use of resources (processors, memory, devices, etc.)? • Is there a possibility of contention for resources with other system components? • Have these contentions been evaluated and determined to be within acceptable limits or risk levels?
Surge capacity	• Does the product have the capability to handle increasing loads as expected (e.g., increased number of transactions, increased complexity of processing, increased number of tracks)?
Adaptability/flexibility	• Can the product be tailored to efficiently handle an appropriate range of performance expectations (transaction rates, numbers of tracks, etc.)? • How is this adaptation accomplished?

Documentation

Design information	• Is the available design information sufficient to determine whether the design is appropriate? • Is it sufficient for determining an integration strategy with other target system components?
Maintenance	• Is the available maintenance information sufficient for installation?

information	• Routine use? • Preventative maintenance? • Fault isolation and recovery?
Training materials	• Are training materials and courses available? • Are they appropriate? • Are they affordable? • Do they cover an appropriate set of stakeholders for the target system? • Are training material/courses tailored for specific stakeholders?
Customization	• Can documentation, training materials, design information, maintenance information, and so forth, be customized for unique target system needs? • What is involved in customization? • What will it cost?
Quality	• Is the quality of all documentation and other information appropriate?
Policy on reproduction	• Can materials be reproduced as needed?

Licenses

Usage/maintenance	• Are standard-usage maintenance licenses appropriate for the target system? • Are license terms negotiable? • Are site licensing and/or quantity discounting available?
Transferability of license	• Are licenses transferable to other operating units or other agents working on behalf of the target organization?
RT licensing	• Are separate licenses necessary/available for development and deployed platforms?

	• What are the terms of these licenses?
Data rights	• What data rights are included in the standard license? • Are they appropriate for the target system? • Must additional data rights be negotiated?
Escrow	• Can source code be escrowed? • What are the costs and stipulations of that escrow? • Is an escrow a reasonable precaution for this system?
Discontinuation	• What rights does the target organization have if the product is discontinued?
Expiration	• What events occur when a license expires? • Is there any notification of impending expiration? • Are licenses “time bombed”?

Functional Capabilities

Appropriateness	• Does the product offer appropriate functional capability? • Is this functionality provided in an appropriate manner (appropriate process, interfaces, quality, etc.)?
Process consistency	• Are the processes supported by the product appropriate for our organization? • What internal (our) processes must change? • How will this change be accomplished?
Industry practices	• Does the product conform to best industry practice? • How was this determined?
Completeness	• What proportion of the intended system capability does the product provide? How was this determined? • What is the gap between the functions necessary in the target

system and those supported by the product?

- What level of effort will be required to provide missing capabilities or enhance deficient capabilities? How should this be accomplished?

Tailoring/customization?

- Is the product suitable "out of the box" or does it require custom construction of scripts, code, tables, and so forth?
- What effort is involved in performing this customization? Who will perform this customization?
- Must this effort be repeated in order to incorporate new product releases?

Excess

- Does the product offer additional functional capability that will not be used? Should not be used?
- What impact does this additional capability have on resource requirements, performance, and so forth?

Architecture

Product

- What architectural paradigms are evident in or employed by the product?
- Are they appropriate for the target system?

System

- Does the product suggest architectural paradigms for the target system?
- Does the product impose architectural restrictions on the system? Are they appropriate?
- What is the impact on other system components?

Product Version Data

Version ID

- What are the version number and release date of the product?
- What additional information is needed to uniquely identify the product (e.g., revision number, patch number)?

Version documentation	•	Identify all product documentation, including user manuals, reference manuals, release notes, installation instructions, known bug lists, and so forth.
Version capabilities	•	What new features, capabilities, and fixes are provided by this uniquely identified product?

Product/System Relationship

System configuration	•	What system configurations does the product work with (or is part of)?
System adaptation	•	What environment variable settings are required?
	•	What specific settings are required for networking, memory, processes, peripheral devices, and so forth?
	•	What adaptation and settings are required of other components of the system in order to work with this product?
Integration	•	What (new) assumptions or expectations does the unique product version make regarding interaction with other components in the environment?
	•	What changes must be made to the assumptions made by the rest of the system regarding the behavior of this version?
	•	What integration guidelines must be followed and specific integration activities undertaken?
Tailoring/modification	•	What tailoring or modification of the product is required?
	•	What settings are required for product variables?
	•	What scripts, tables, schemas, 4GL code, etc., are required? Why are these required?
	•	Were workarounds considered? Why were they rejected?
	•	Has the tailoring/modification been approved by an authoritative control board?

- Was the product vendor consulted? What was the vendor's response?
- Will tailoring/modification affect the contract in any way (e.g., changes in license fees, changes in maintenance practices or responsibilities)?
- What assurance is there that the modified version will become part of the standard commercial offering?
- Who has/will perform the tailoring/modification?
- Is all applicable test data and verification of test passage under configuration control?

Appendix D: Cost Comparison Spreadsheet

The following page contains the Cost Comparison Spreadsheet.

Table 2: Cost Comparison Spreadsheet

Item #	Component	Quantity	Unit Price	Extended Price	Cumulative Price
SOFTWARE					
1	Concurrent Seats	6	3,000	18,000	18,000
2	Accounting Modules	1	3,000	3,000	21,000
3	Scheduler	1	3,000	3,000	24,000
4	Professional Software License	1	1,500	1,500	25,500
5	Data Collection Software License	1	3,200	3,200	28,700
6	View Software license	1	2,000	2,000	30,700
7	Data Collection - PC Driver	10	400	4,000	34,700
DISCOUNT					
10	System Discount	1	36%	(12,492)	**22,208**
THIRD PARTY SOFTWARE					
8	Report Software	1	469	469	22,677
			-	-	-
HARDWARE					
11	Heavy Duty Scanner	4	995	3,980	26,657
12	Light Duty Scanner	6	225	1,350	28,007
13	Data Collection Server	1	1,200	1,200	29,207
14	Additional Network Controllers	0	225	-	29,207
15	Data Collection Terminal	4	825	3,300	32,507
16	Server	1	9,000	9,000	41,507
17	Shop floor workstation	4	1,200	4,800	46,307
18			**SUBTL HRD**	**23,630**	46,307
SERVICES					
19	Workshop for Job Control	1	250	250	46,557
20	Workshop for Accounting	1	250	250	46,807
21	Onsite consulting (front office?)	24	135	3,240	50,047
22	Onsite consulting for Data Collection	16	135	2,160	52,207
23	Onsite Custom training 6-9 people	3	1,800	5,400	57,607
RECURRING FEES			**SUBTL SRV**	**11,300**	
24	Annual Subscription Fee	1	1,200	1,200	58,807
25	Third Party S/W Maintenance	1	12%	56	58,863
26	Prepaid Support 6 months Access	0.5	12%	2,082	60,889
27	Prepaid Support 12 months Access	1	12%	4,164	-
28	Prepaid Support 6 months SQL Server	0.5	15%	2,603	61,410
29	Prepaid Support 12 months SQL Server	1	15%	5,205	-
			SUBTL MNT	5,420	
	After 5 years maintenance			**87,990**	

Item #	Component	Quantity	Unit Price	Extended Price	Cumulative Price
SOFTWARE					
1	Premium Edition + Labor Data Collection	6	1,533	9,195	9,195
2	Data Collection only users	8	595	4,760	13,955
3	Web Order Status	1	750	750	14,705
DISCOUNT					
3	System Discount	0	-	-	**14,705**
THIRD PARTY SOFTWARE					
4	Accounting	5	148	740	15,445
5	Report Writer	1	469	469	15,914
HARDWARE					
6	Barcode Scanner w/Wedge Decoder	14	313	4,382	20,296
7	Barcode Scanner USB Connector	14	68	952	21,248
8	Barcode Scanner Auto-Sense Cradle	14	69	966	22,214
9	Server	1	9,000	9,000	31,214
10	Shop floor workstation	8	1,200	9,600	40,814
8		0	-	-	40,814
			SUBTL HRD	**24,900**	-
					43,214
SERVICES					
9	Onsite consulting	2	1,200	2,400	43,214
10			-	-	43,214
11			-	-	43,214
12			-	-	43,214
13	Onsite Custom training	4	1,200	4,800	48,014
RECURRING FEES			**SUBTL SRV**	**7,200**	
14	Premium Edition + Labor Data Collection, Maint. & Support	1	40%	5,582	53,596
15	Maintenance - Web Order Status	0	20%	150	53,746
16	Third Party S/W Maintenance (est.)	1	12%	145	53,891
17	0		**SUBTL MNT**	5,877	
				83,276	

Item #	Component	Quantity	Unit Price	Extended Price	Cumulative Price
SOFTWARE					
1	Shop System 1st User	1	8,500	8,500	8,500
2	Shop System 2nd-6th User	5	1,900	9,500	18,000
3	Web view software	1	1,900	1,900	19,900
4					19,900
5					19,900
6					19,900
7					19,900
DISCOUNT					-
10	System Discount	0	-	-	**19,900**
THIRD PARTY SOFTWARE			-	-	-
8	Report Software	1	469	469	20,369
			-	-	-
HARDWARE			-	-	-
11	Data Collection Starter Kit - Terminals,guns, controller	2	2,000	4,000	24,369
12	Additional Data Collection terminals & guns	2	995	1,990	26,359
13	Bar code guns for PCs	10	525	5,250	31,609
14	Server	1	9,000	9,000	40,609
15	Shop floor workstation	4	1,000	4,000	44,609
16	Front office workstation	0	1,100	-	44,609
17	Data Collection PC only	1	1,800	1,800	46,409
			SUBTL HRD	**26,040**	46,409
					-
SERVICES					
19	Onsite consulting	1	950	950	47,359
20	Onsite training	2	951	1,902	49,261
21			-	-	49,261
22			-	-	49,261
23	Offsite training unlimited		-	-	49,261
RECURRING FEES			**SUBTL SRV**	**2,852**	-
24	Prepaid Support 6 months	0.5	12%	1,194	50,455
25	Data Collection Support	0.5	144	72	50,527
26	Payroll interface Support	0.5	50	25	50,552
27	Third Party S/W Maintenance	1	12%	56	50,608
28	Prepaid Support 12 months	1	12%	2,388	-
29	Data Collection Support 12 months	1	144	144	-
30	Payroll interface Support 12 months	1	50	50	-
			SUBTL MNT	2,638	
				63,800	

Appendix E: Manufacturing Execution Systems Product Survey

The following pages contain the Manufacturing Execution Systems Product Survey, a product comparison matrix to aid in the software selection process.

This matrix was a snapshot circa December 2001 by Craig Schlenoff of NIST; any commercial product identified in this document is for the purpose of describing a software environment. This identification does not imply any recommendation or endorsement by NIST, SEI, CMU, or TIDE.

Table 3: Manufacturing Execution Systems Product Survey

Product	TEAM	Visual Job Shop	Job Boss	Resource Manager	Vista	MISys/2000 Manufacturing System	PC/MRP	MRP PLUS	DBA	E2 Systems
Company	Georgia Tech	Lilly	Kewill	UserSolutions	Epicor	Manufacturing Information Systems	PC/MRP	Horizon Software, Inc.	DBA Software	Shoptech Industrial Software Corp.
URL	www.mfgteam.com	www.lillyproducts.com	www.jobboss.com	www.usersolutions.com	www.epicor.com	www.misysinc.com	www.pcmrp.com	www.mrpplus.com	www.dbasoftware.com	www.shoptech.com
Phone	404-894-4472, 770-535-5843	603-926-9696	800-777-4334 x1478	800-321-USER	800-449-6772, x5087, x5209	802-457-4600	408-248-6445	877-MRP-2-ERP	1-800-995-1959	800-525-2143
Cost	free	about $1500/seat plus $500 for training	typical cost - $10K-$15K with training	complete single user - $3900, training - no charge for phone support, on site - $1250/day	8K-10K	12K, training - 3K total for whole company over internet	$1500 for software, training - $1500 for first day, $1000 for extra days		$399/user	$8500 for one user, $2100 for additional user
Users	few	3,000 - visual manufacturing, 50 - visual job shop - just launched	3,000 customers	several thousands worldwide	3,000 companies	6,000 companies	3500 companies	7400 companies worldwide	4,000 companies	2,000 companies
Been in Business	since 1965	since 1992	since 1984	since 1991	since 1976	since 1983	since 1985	since 1985	since 1991	since 1982
Support Make-to-Order and Engineer-to-Order	yes	yes	yes	yes (general purpose)	yes	make-to-order	yes	yes	yes	yes
Integrate with Peachtree	yes	yes	no	yes	not natively - need to extend	no - only to ACCPAC	no		no	only with Peachtree payroll
Front-End User Interface	Access Forms	windows	windows	Excel	windows	windows	windows	windows	windows - no GUI	windows
Support Quoting and Estimation	yes	yes	yes	yes	yes	Level 2	yes	yes	yes	yes
Support What-If Scenarios	yes, ???	premium version - extra $500 per seat	yes	yes	yes	yes	yes	yes	no	yes

Table 3: Manufacturing Execution Systems Product Survey

Product	**TEAM**	**Visual Job Shop**	**Job Boss**	**Resource Manager**	**Vista**	**MISys/2000 Manufacturing System**	**PC/MRP**	**MRP PLUS**	**DBA**	**E2 Systems**
Support Finite Capacity Scheduling	yes	premium version - extra $500 per seat	yes	yes	yes	infinite only	infinite only	yes	yes	just infinite
Product	**TEAM**	**Visual Job Shop**	**Job Boss**	**Resource Manager**	**Vista**	**MISys/2000 Manufacturing System**	**PC/MRP**	**MRP PLUS**	**DBA**	**E2 Systems**
Support Inventory Control	yes	yes	yes	yes	yes	Level 1	yes	yes	yes	yes
Ability to Export Information out to Feed into Web Pages	yes - use Microsoft Access web-interface capabilities	ODBC compliant - would be an ODBC call - VB programming or Access macro	can email from quoting screen, custom dept can pull out information from system and input it into another system, can import into any Microsoft application, Microsoft solution provider	same capabilities that are available in Microsoft Office - depends on which version of Office they have	would need to export data - can be done	yes - ODBC calls, export formats (ASCII)	export to Excel, HTML or email	yes	in general, no, but working with third-party EDI company (Technology Management Program - Bob Anderson - San Diego - 760-431-8133)	easy to export information - to Excel spreadsheet, ODBC compliant
Support Planning and Scheduling	yes	yes	yes	yes	yes	Level 2	yes	yes	yes	yes
Support Purchasing	yes	yes	yes	yes	yes	Level 1	yes	yes	yes	yes
Support Shop Floor Control	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Support Sales Order Entry and Management	yes	yes	yes	yes	yes	Level 2	yes	yes	yes	yes

Table 3: Manufacturing Execution Systems Product Survey

Product	TEAM	Visual Job Shop	Job Boss	Resource Manager	Vista	MISys/2000 Manufacturing System	PC/MRP	MRP PLUS	DBA	E2 Systems
Forward and Backward Scheduling	yes	yes	yes	yes	yes	Level 2	neither - can put in a due date and system notifies you if you are going to miss it	yes	yes	yes
Track tool usage for replacement	need an extension	can be done but need customization	not explicitly - but can be done - no customization needed	no	quantity-based can be done, hours-based would be more difficult but can be done	Level 3	no - possible workaround	yes	yes	yes
Log actual times and costs	yes	yes	yes	yes	yes	Level 3	yes	yes	yes	yes
Basic Reporting capabilities	yes	yes	yes	yes	yes	Level 3	yes	yes	yes	yes
Collect labor time	yes	yes	yes	not explicitly in software, but software can be expanded to accommodate this	yes	yes	yes	yes	yes	yes
Notes	open source, developed very generically based on APICS (American Production Inventory Control Society) principles	was spoken about very highly from the folks at Georgia Tech	positioned for larger companies	EXCEL-based, so you need to be comfortable with EXCEL to feel comfortable with the interface. Recommended by SPIRC (Pittsburgh MEP office)	allows for some customiza-tion, good stable product					

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All URLs are accurate as of the publication date of this report.

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Small manufacturing enterprises (SMEs) face a number of challenges when selecting and implementing advanced manufacturing technologies. These challenges may include the lack of awareness of the specific technologies and commercial products available, the lack of ability to select the appropriate product, and the lack of skill sets needed to utilize the selection techniques.

This paper documents the actual process and benefits of advanced software technologies adoption by two SMEs. Considerations for defining requirements and selecting a software product are described. This note explains the issues involved for SMEs, presents methods they can use, and provides artifacts used in this documented case.

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